An Evaluation of Photochemical Model Estimated PM2.5 and Ozone using MM5 and WRF Inputs for the Western United States

Kirk Baker

U.S. Environmental Protection Agency

Ad-Hoc Meteorological Modelers Meeting

June 2009

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Western U.S. Sensitivity Runs

MM5 v3.7.4

- Pleim-Xiu PBL and land surface schemes
- Kain-Fritsh 2 cumulus parameterization
- Reisner 2 mixed phase moisture scheme
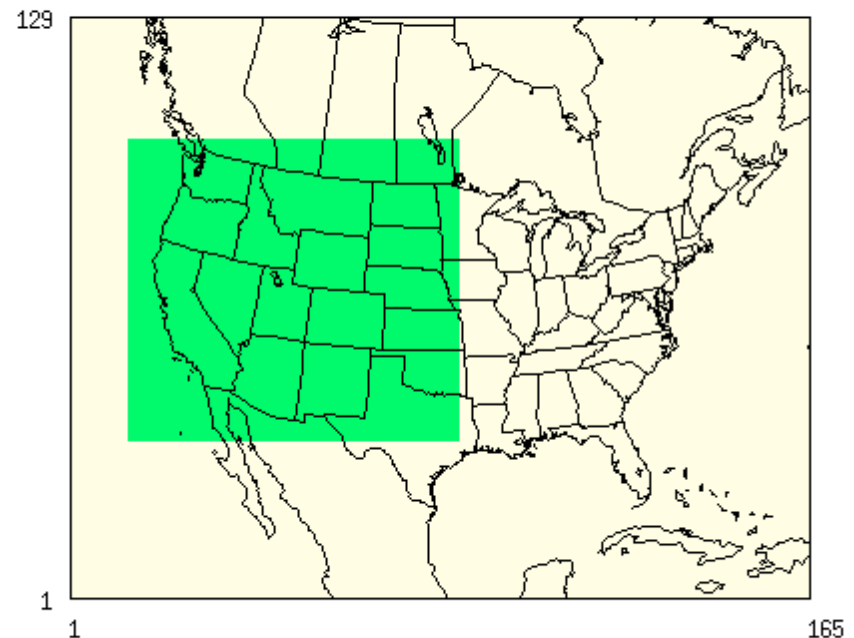- RRTM longwave radiation scheme
- Dudhia shortwave radiation scheme

WRF v3.0.1

- YSU PBL
- Janjic Eta Surface Layer scheme
- Kain-Fritsh (new Eta) cumulus
- Thompson Graupel moisture scheme
- RRTM longwave radiation scheme
- Dudhia shortwave radiation scheme
- The **NOAH** and **Pleim-Xiu** land surface schemes are each applied with a WRF simulation.

CMAQ v4.7

- CB05 gas phase chemistry
- ISORROPIA inorganic chemistry
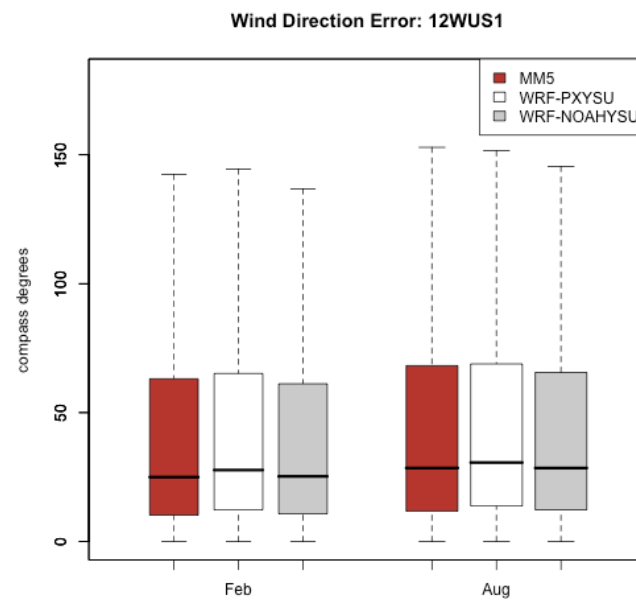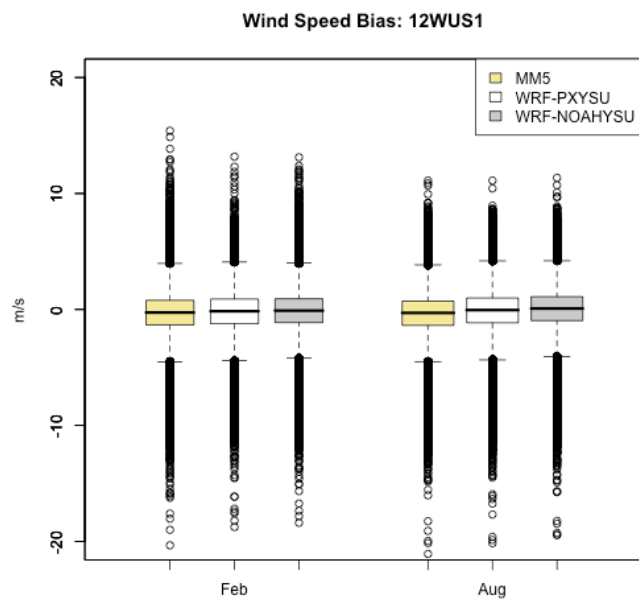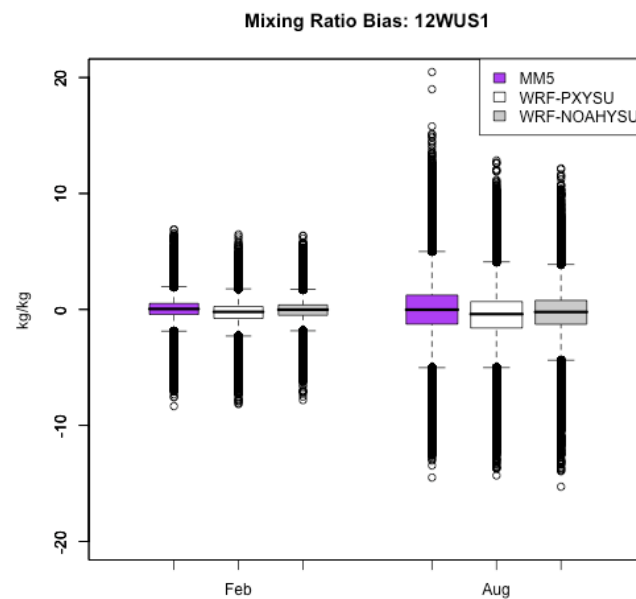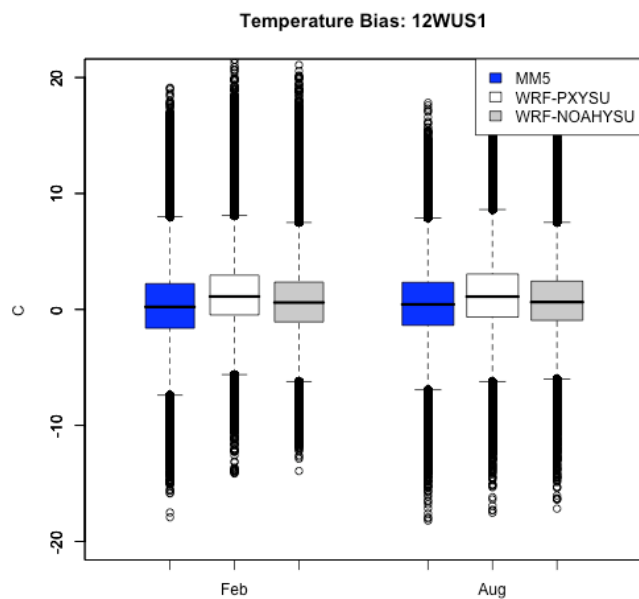
All models applied to February and August 2005 for the 12 km Western U.S. domain

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T, MR, WS, and WD

Temperature Bias: 12WUS1

Mixing Ratio Bias: 12WUS1

Wind Speed Bias: 12WUS1

Wind Direction Error: 12WUS1
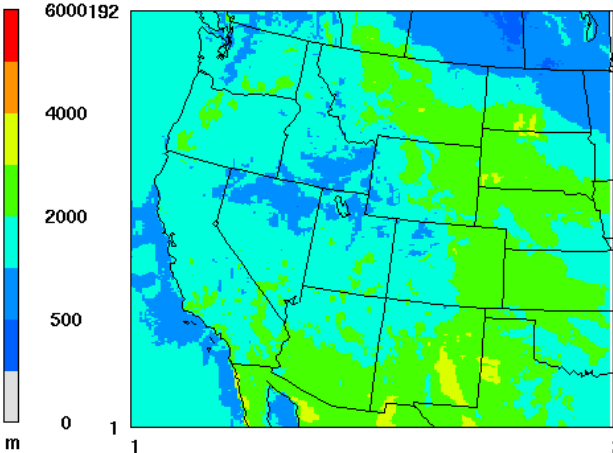
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Monthly Max. Predicted PBL
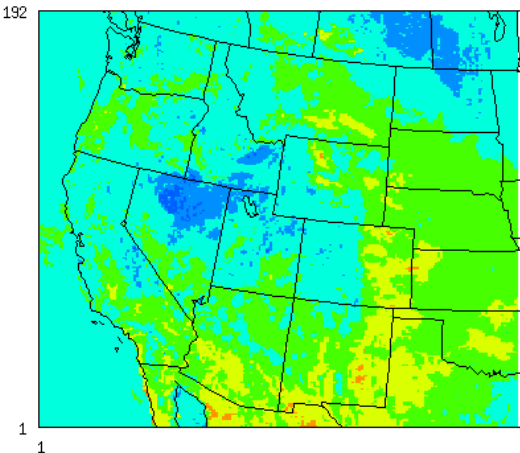
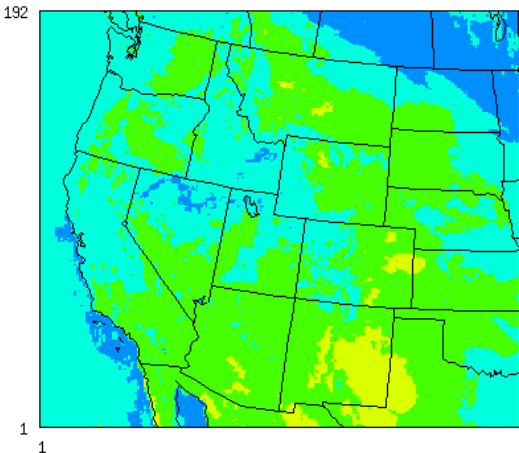## MM5   WRF-YSU   WRF-PX
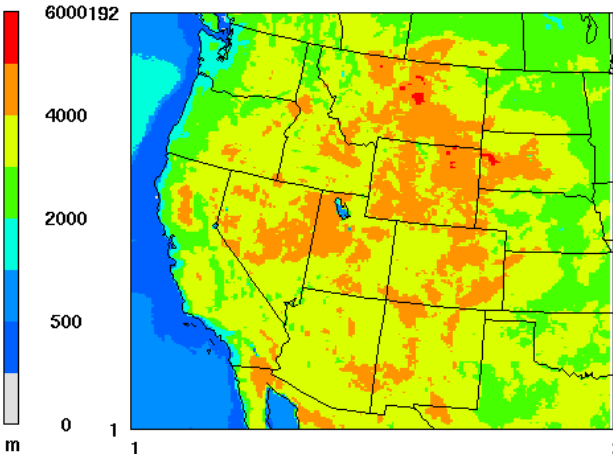

February 1,2005 1:00:00
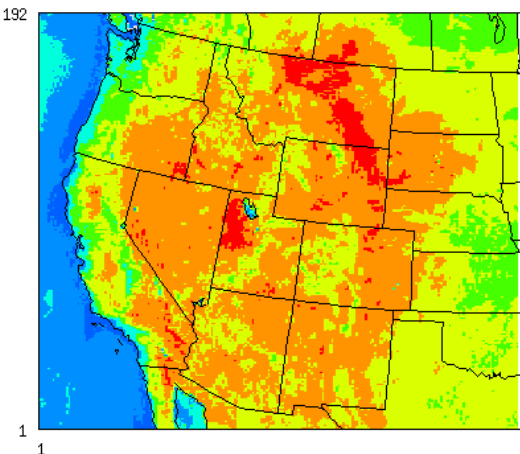Min=   417 at (168,192), Max=   3815 at (143,17)

February 1,2005 1:00:00
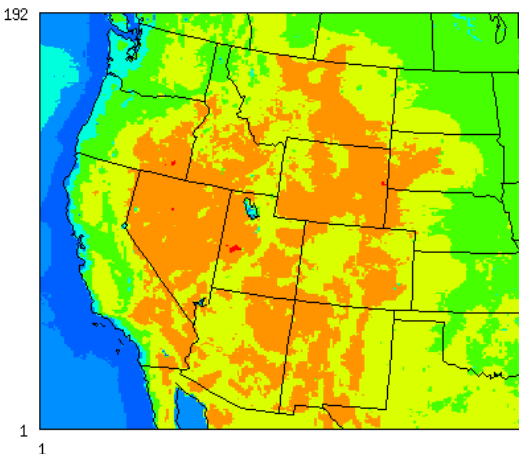Min=   283 at (102,81), Max=   4406 at (127,125)

February 1,2005 1:00:00
Min=   445 at (57,34), Max=   3998 at (143,25)

August 1,2005 1:00:00
Min=   75 at (43,189), Max=   5154 at (143,121)

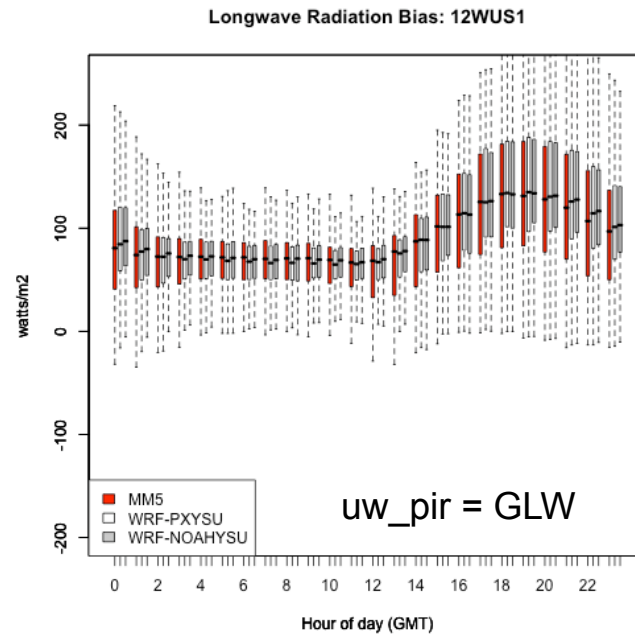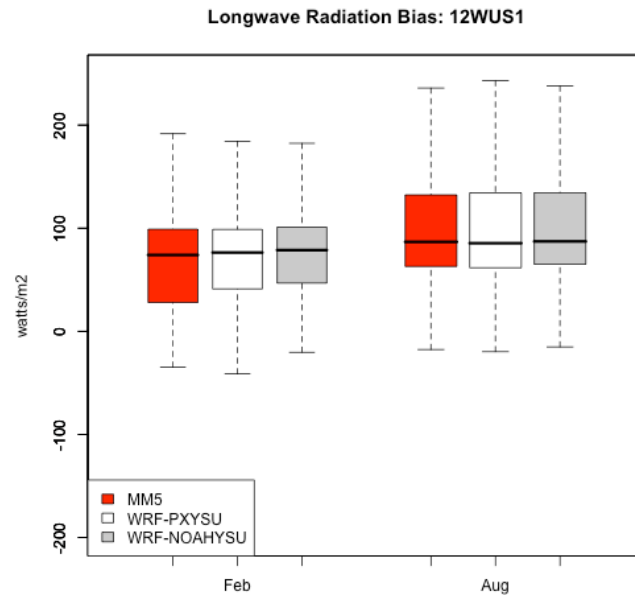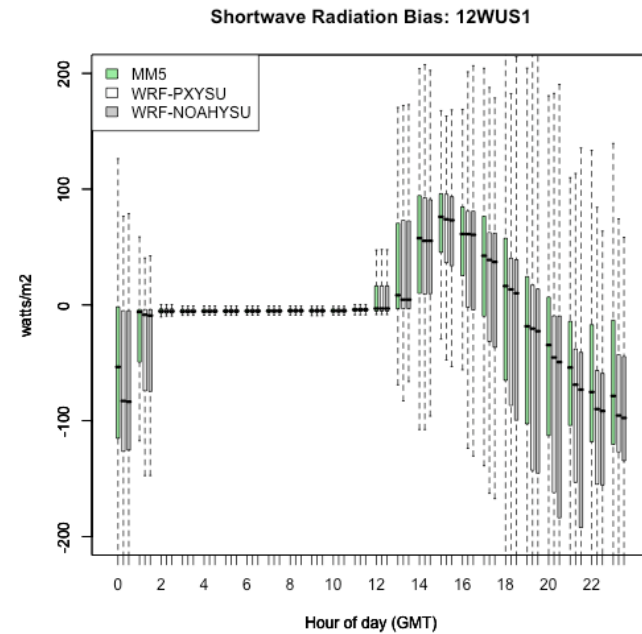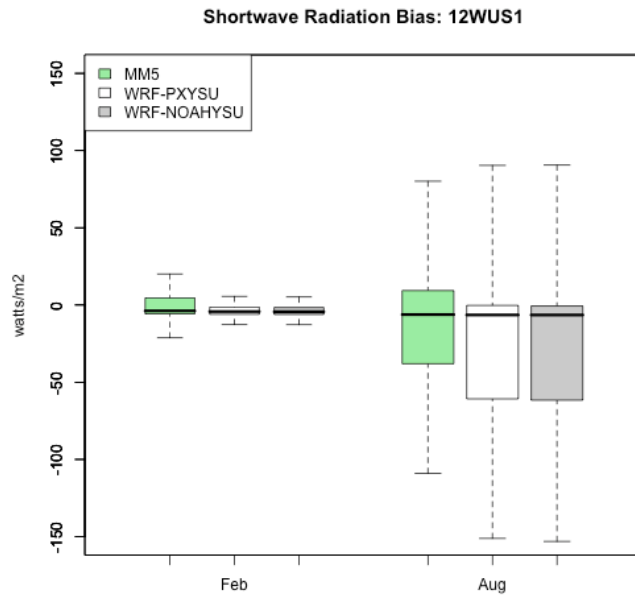August 1,2005 1:00:00
Min=   79 at (43,184), Max=   6811 at (116,176)

August 1,2005 1:00:00
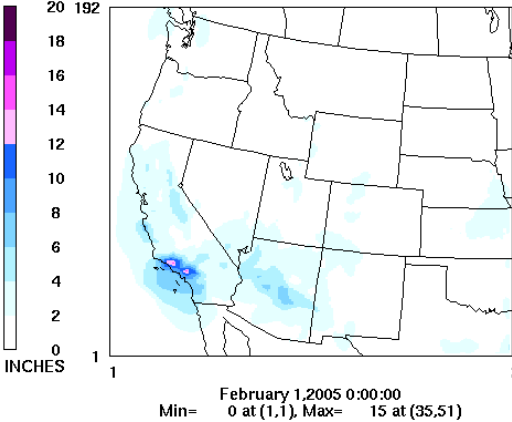Min=   119 at (56,36), Max=   5206 at (87,83)

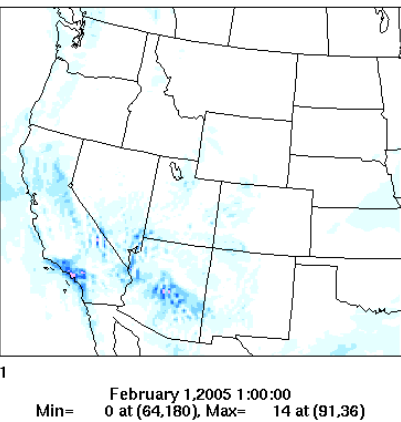06/24/2009   4

Radiation

Shortwave Radiation Bias: 12WUS1

Shortwave Radiation Bias: 12WUS1

Longwave Radiation Bias: 12WUS1

Longwave Radiation Bias: 12WUS1

uw_pir = GLW

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Rainfall: Monthly Total

CPC Analysis | MM5 | WRF-YSU | WRF-PX

February 1,2005 0:00:00
Min= 0 at (1,1), Max= 15 at (35,51)

February 1,2005 1:00:00
Min= 0 at (64,180), Max= 14 at (91,36)

February 1,2005 1:00:00
in= 0 at (64,180), Max= 13 at (45,46)

February 1,2005 1:00:00
.n= 0 at (61,174), Max= 14 at (45,46)

CPC Analysis | MM5 | WRF-YSU | WRF-PX

August 1,2005 0:00:00
Min= 0 at (1,1), Max= 14 at (205,61)

August 1,2005 1:00:00
Min= 0 at (77,61), Max= 35 at (114,74)

August 1,2005 1:00:00
Min= 0 at (26,1), Max= 22 at (104,1)
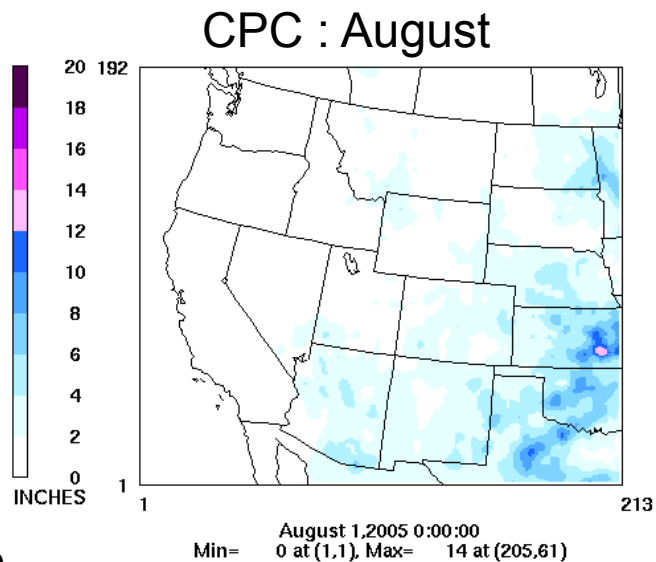
August 1,2005 1:00:00
Min= 0 at (70,4), Max= 25 at (182,8)
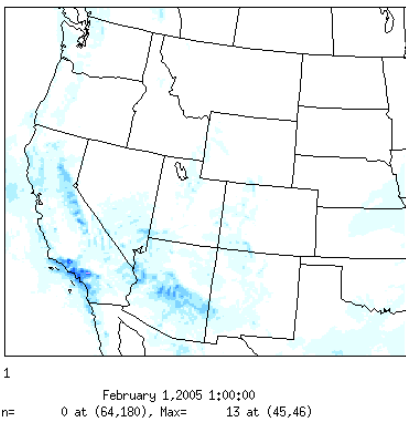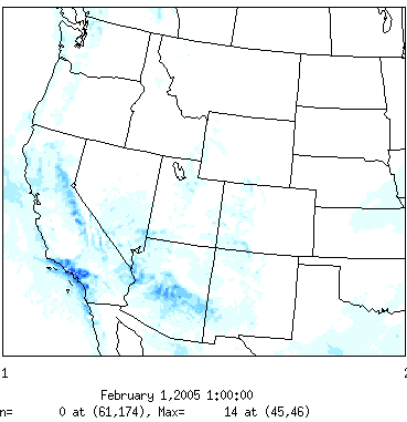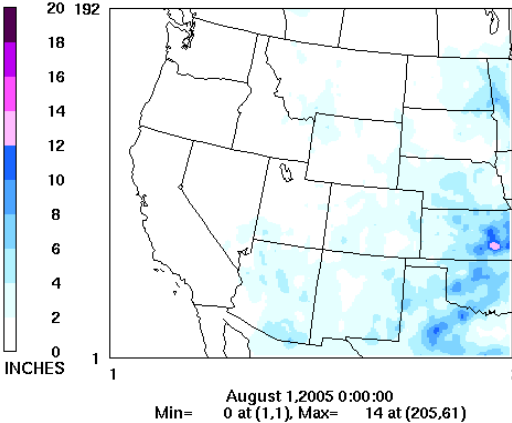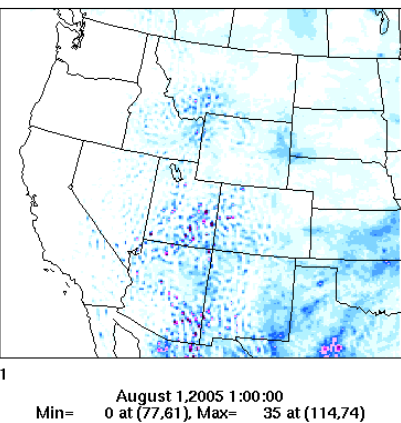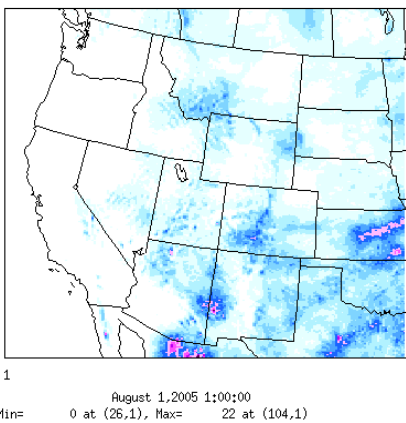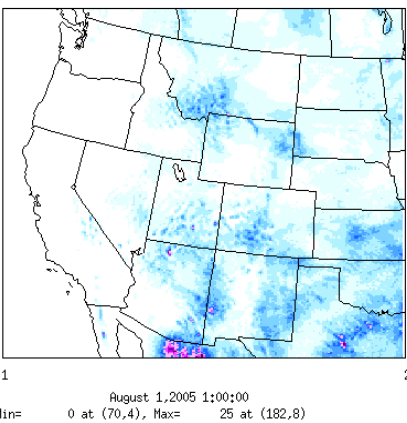
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Rainfall: Observation Analysis Monthly Total

CPC : January

February 1,2005 0:00:00
Min= 0 at (1,1), Max= 15 at (35,51)

PRISM : January

March 1,2005 0:00:00
Min= 0 at (155,27), Max= 18 at (45,46)

CPC : August

August 1,2005 0:00:00
Min= 0 at (1,1), Max= 14 at (205,61)

PRISM : August

August 28,2005 0:00:00
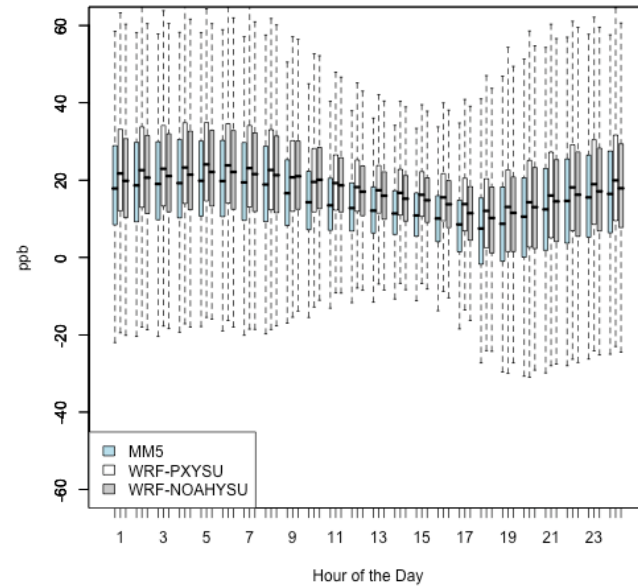Min= 0 at (155,27), Max= 12 at (206,62)
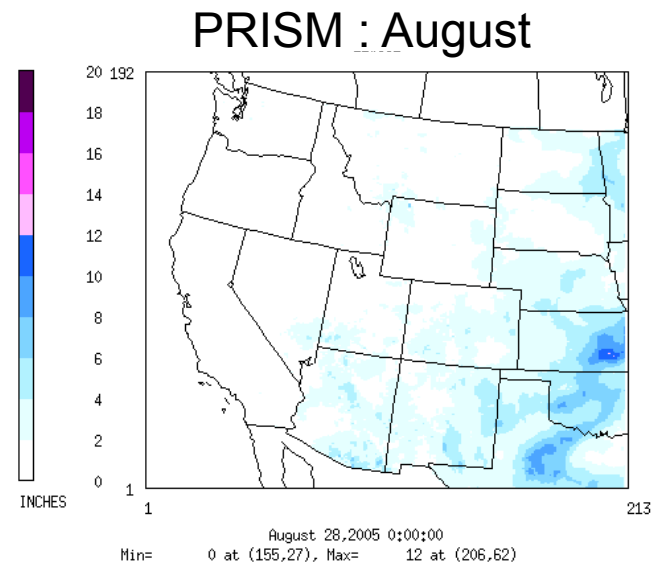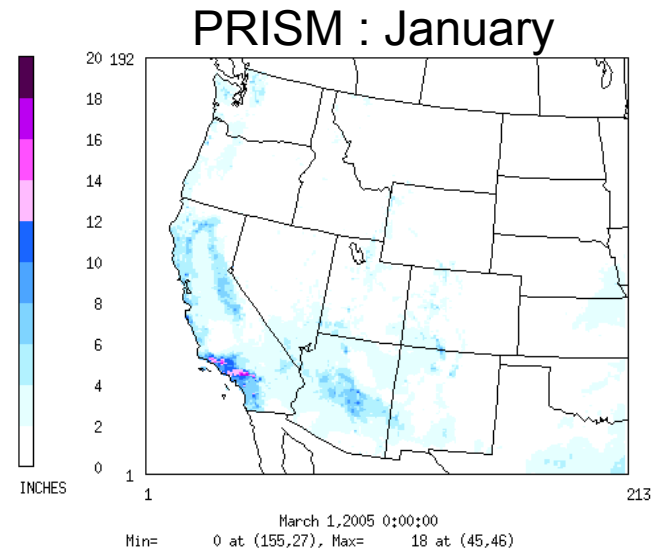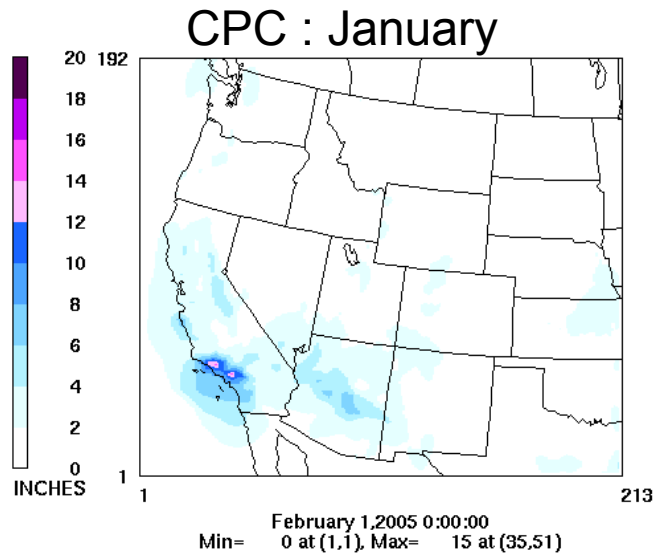
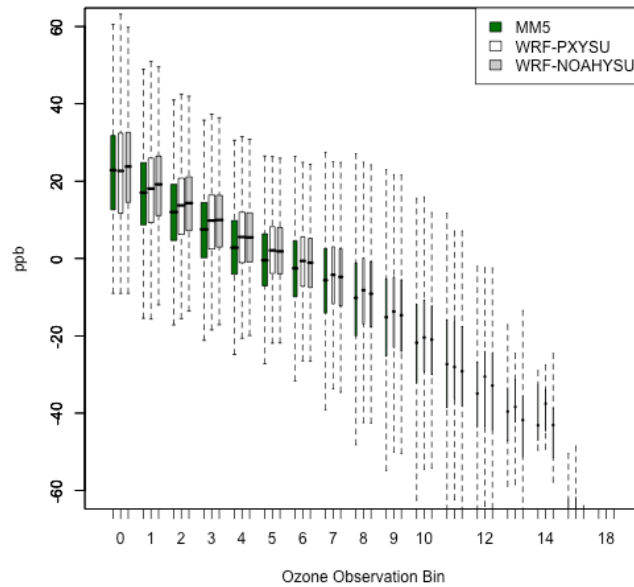06/24/2009

PM2.5 Species
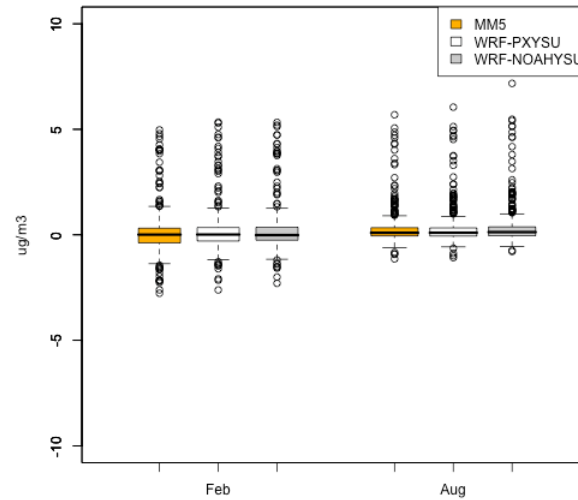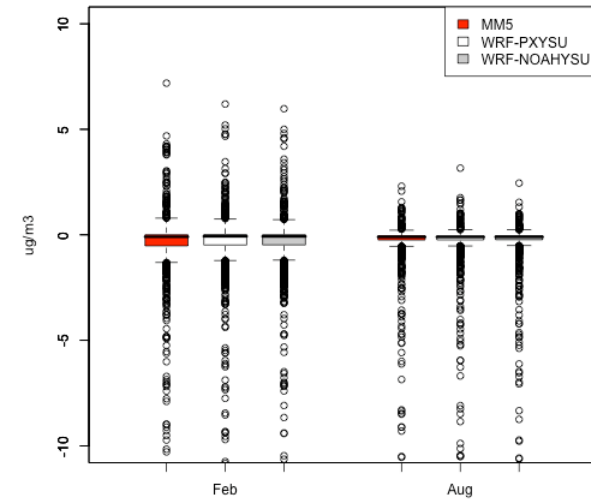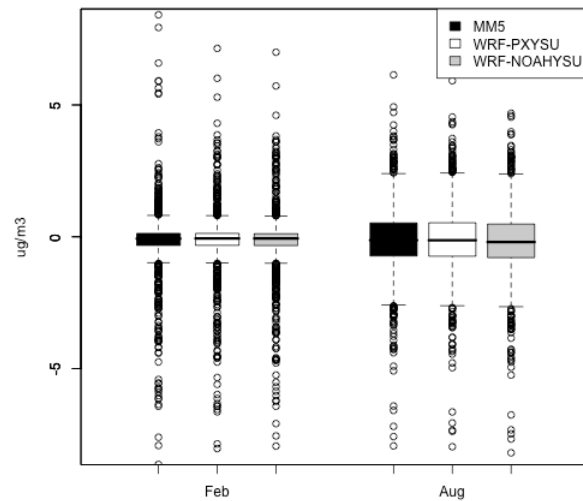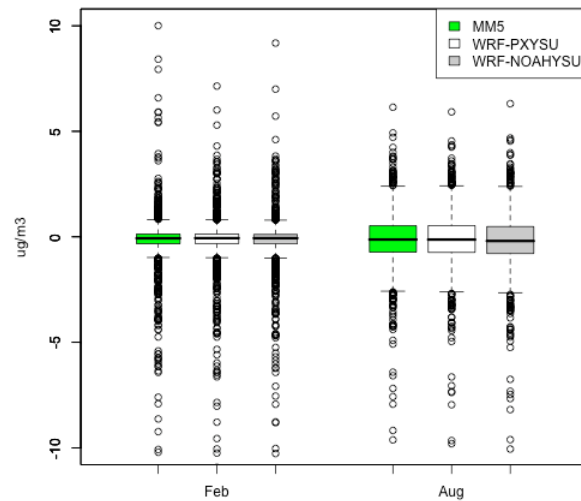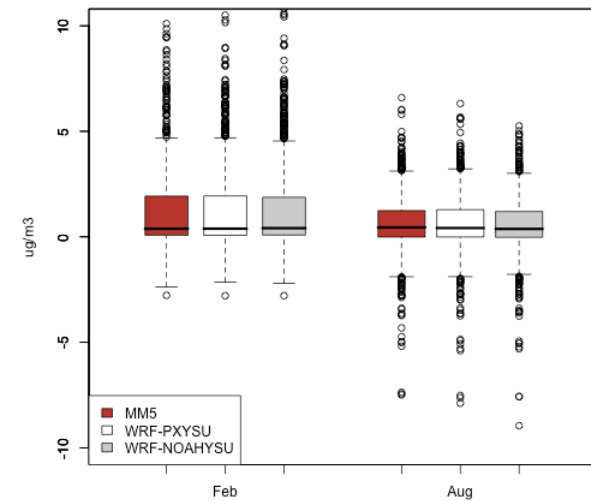
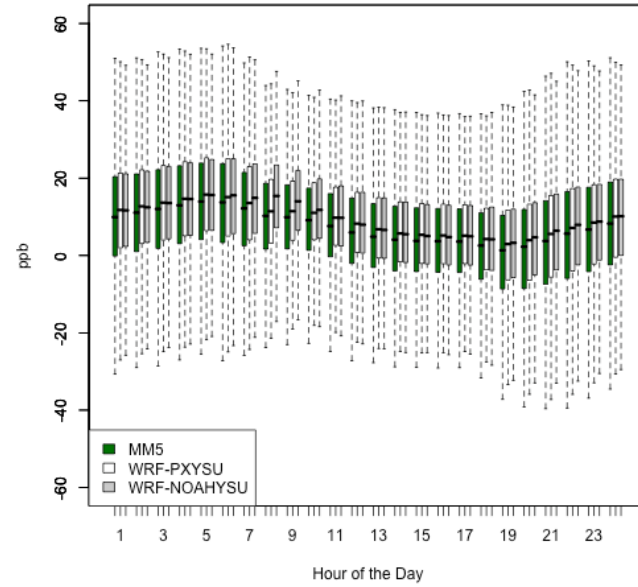# Ozone

February 2005 Ozone Bias: 12WUS1

February 2005 Ozone Bias: 12WUS1

August 2005 Ozone Bias: 12WUS1

August 2005 Ozone Bias: 12WUS1

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Remarks

- Consistent CMAQ estimates for ozone and PM2.5 in the western United States using MM5 and WRF inputs

- This supports the transition from MM5 to WRF for retrospective photochemical model applications

- All meteorological simulations over-predict early morning shortwave downward radiation and under-predict mid-day SWDOWN

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An Examination of the Impact of Clouds on CAMx Ozone and PM2.5 Sulfate Ion

Kirk Baker

U.S. Environmental Protection Agency

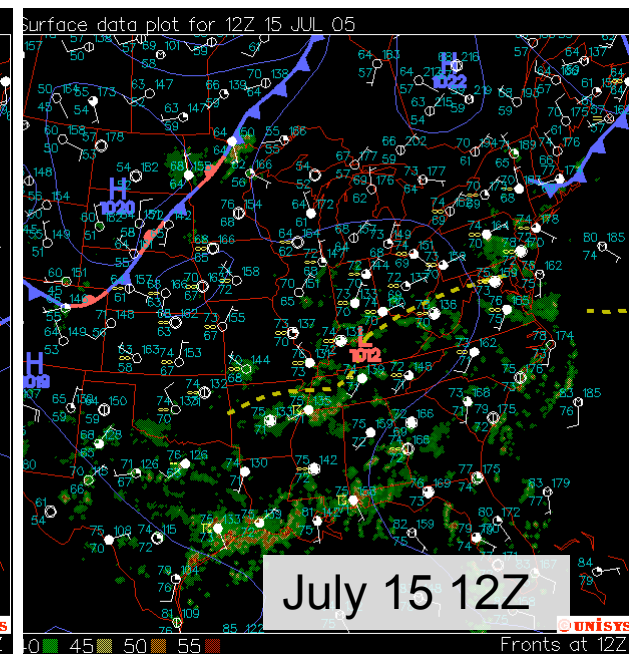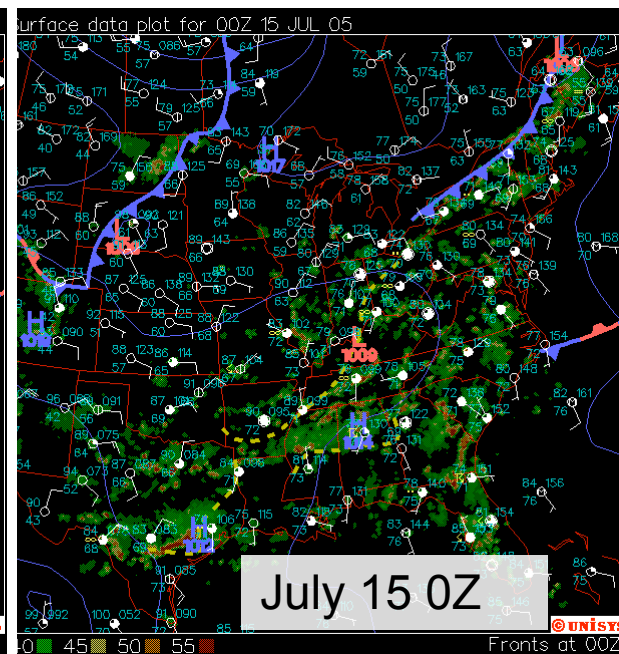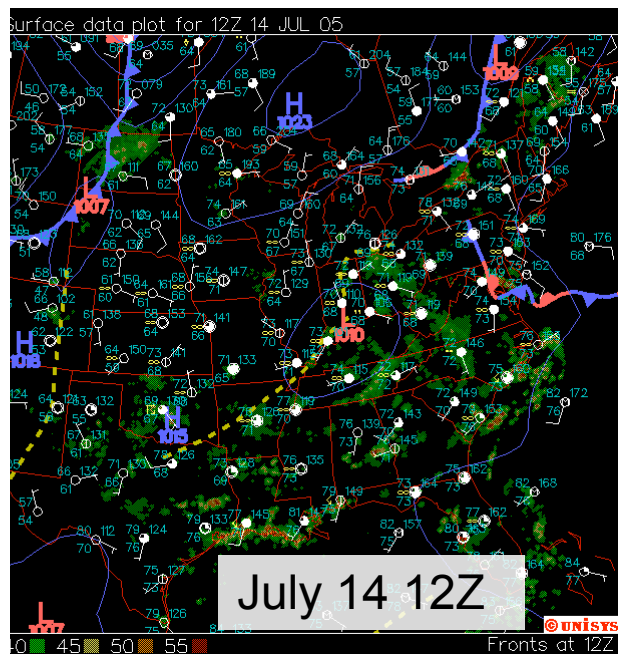Ad-Hoc Meteorological Modelers Meeting
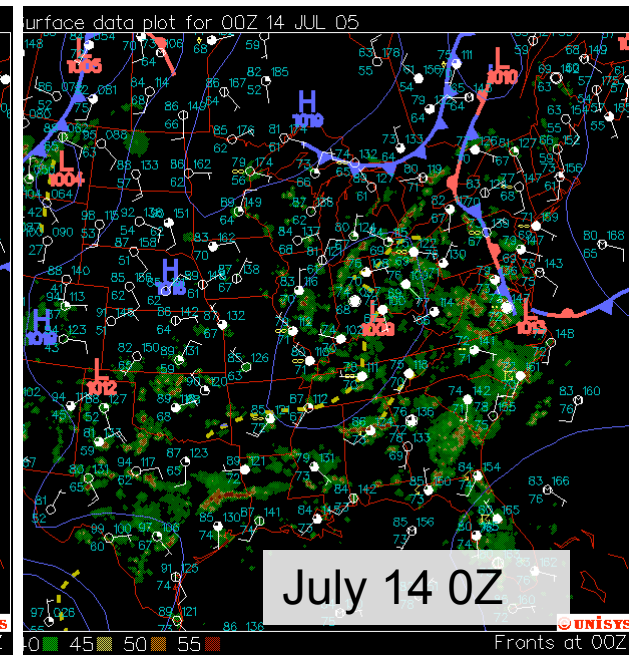
June 2009

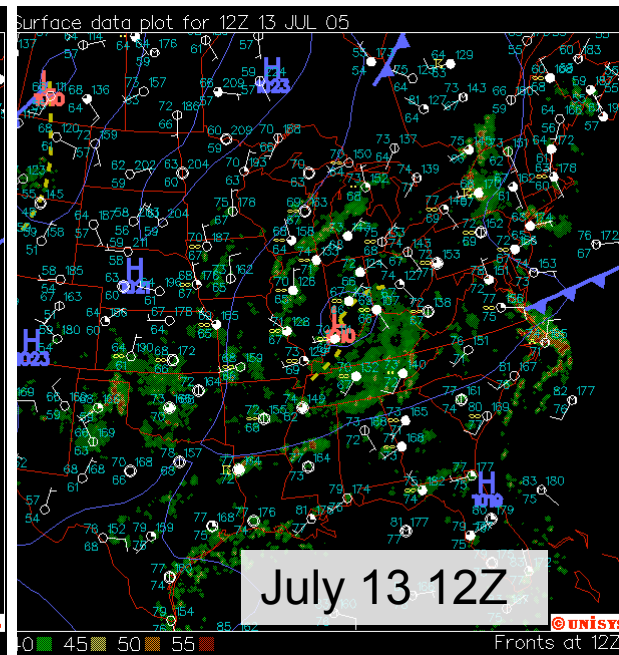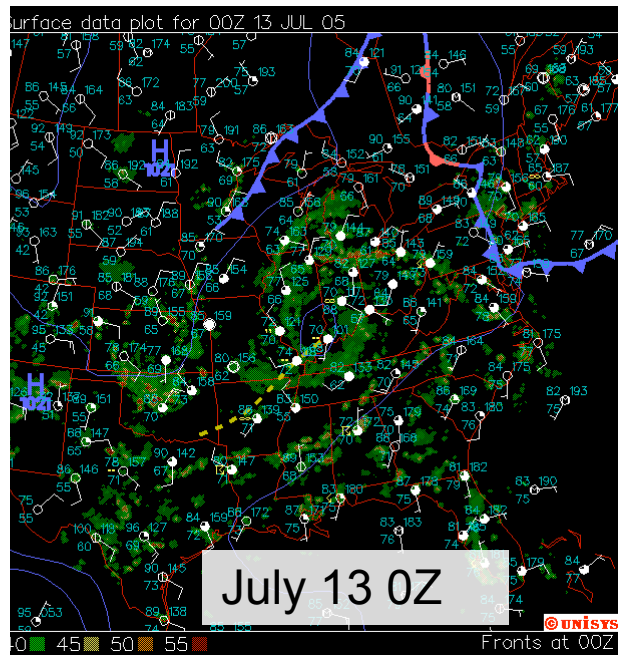06/24/2009   11

Background

- Eastern US 12 km simulation
- July 1-16, 2005 episode

- Large low pressure system stagnating over the Ohio Valley for days
- CAMx estimating large amounts of ozone over the Ohio Valley where little was measured on July 13-14, 2005

- Base simulation: CAMx v5.01
- COPD1 sensitivity: increase the cloud optical depth (tau) scattering term coefficient by an order of magnitude (from 3 to 30) where cloud water is present (K. Baker @ EPA)
- COPD2 sensitivity: add sub-grid cloud diagnosis to the optical depth calculation in mm5camx (from C. Emery @ ENVIRON)

Notes

- Cloud optical depth (COPD) estimated in mm5camx using grid resolved cloud water, ice, rain, snow, and graupel output from MM5

- COPD is used in CAMx to estimate multiple internal terms used for photolysis rate attenuation (energy, fcloud)

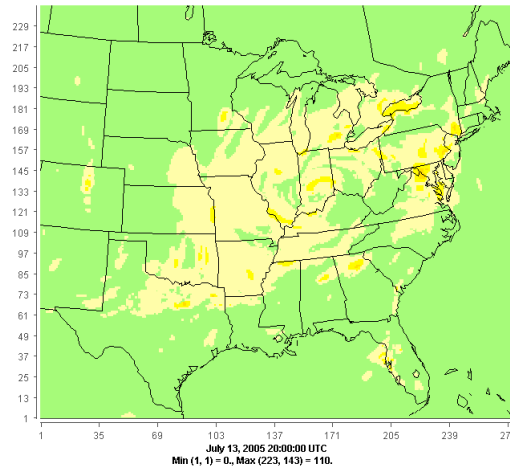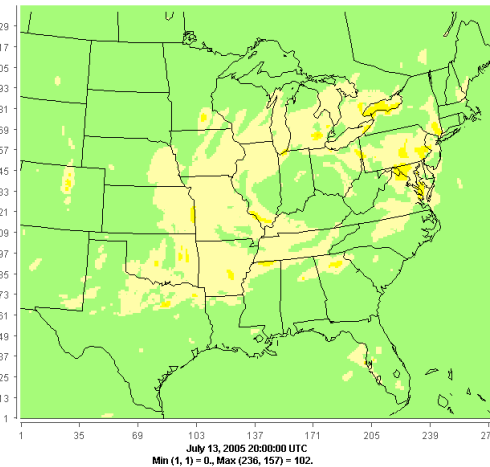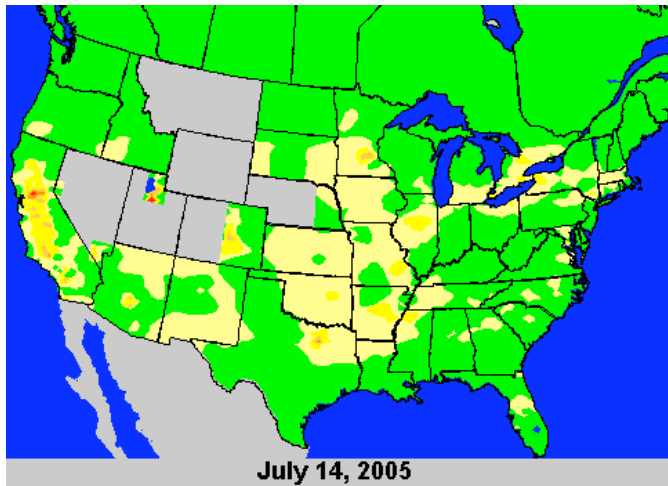- Both CAMx and CMAQ use RADM aqueous phase chemistry with some implementation differences

Surface data plot for 00Z 13 JUL 05 — July 13 0Z

Surface data plot for 12Z 13 JUL 05 — July 13 12Z

Surface data plot for 00Z 14 JUL 05 — July 14 0Z

Surface data plot for 12Z 14 JUL 05 — July 14 12Z

Surface data plot for 00Z 15 JUL 05 — July 15 0Z

Surface data plot for 12Z 15 JUL 05 — July 15 12Z

1-Hr Ozone

Observations

July 13, 2005

July 13 - Base

July 13, 2005 20:00:00 UTC
Min (1, 1) = 0., Max (223, 143) = 110.

July 13 – COPD1 sens

July 13, 2005 20:00:00 UTC
Min (1, 1) = 0., Max (236, 157) = 102.

Observations

July 14, 2005

July 14 - Base

July 14, 2005 20:00:00 UTC
Min (1, 1) = 0., Max (185, 89) = 127.

July 14 – COPD1 sens

July 14, 2005 20:00:00 UTC
Min (1, 1) = 0., Max (224, 146) = 115.
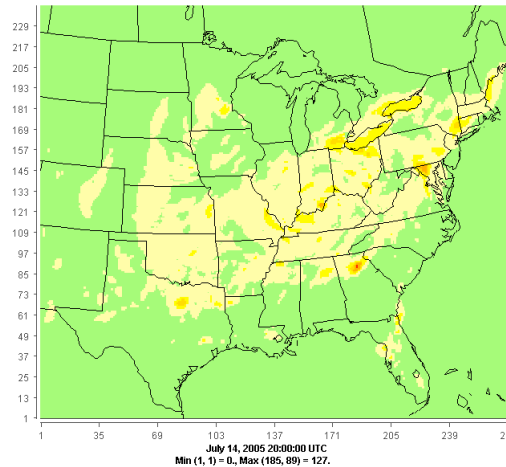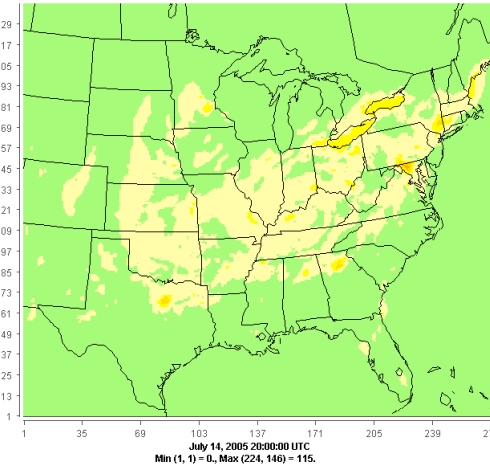
1-Hr Ozone

Difference Plots:
Sens - Base
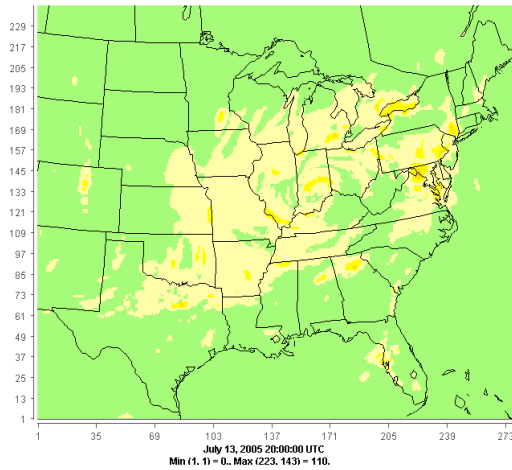
July 13 - Base
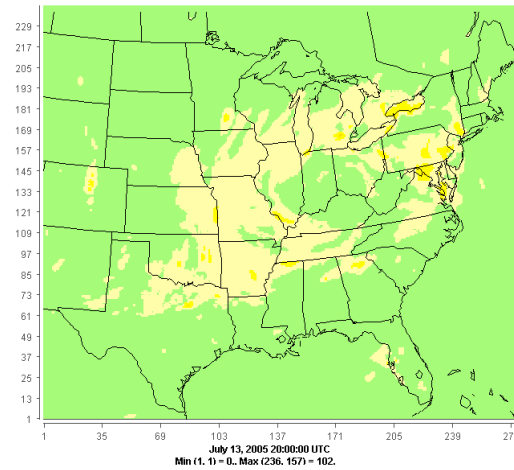
July 13 – COPD1 sens
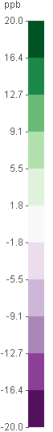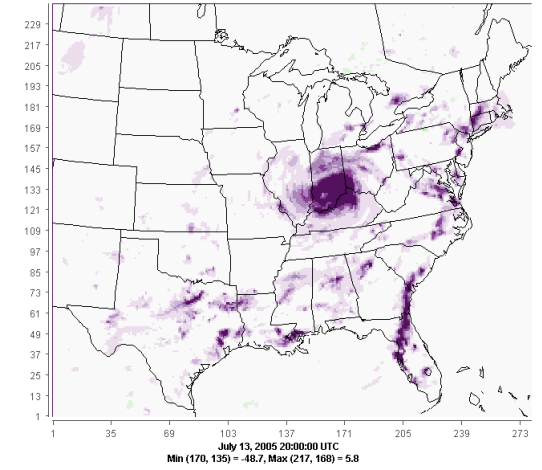
Layer 1 O3[1]-O3[2]
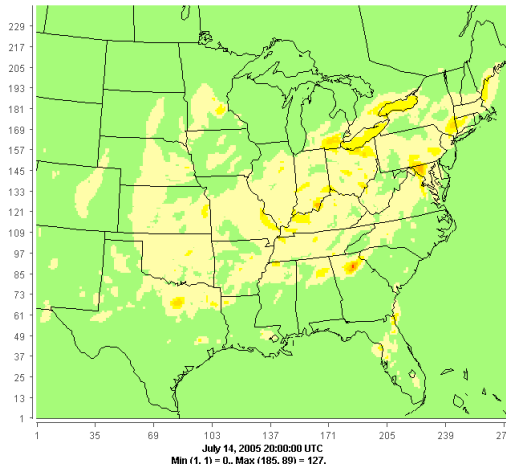
July 14 - Base
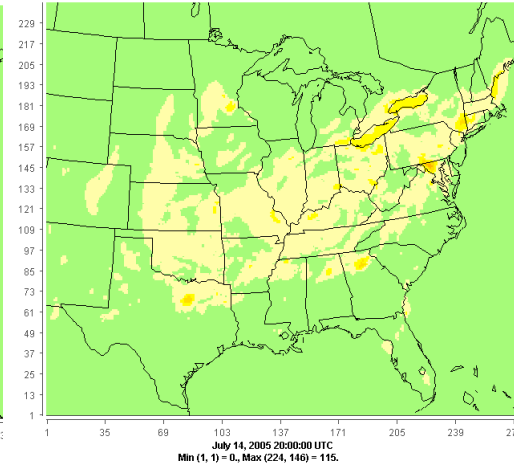
July 14 – COPD1 sens
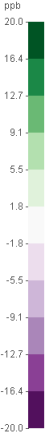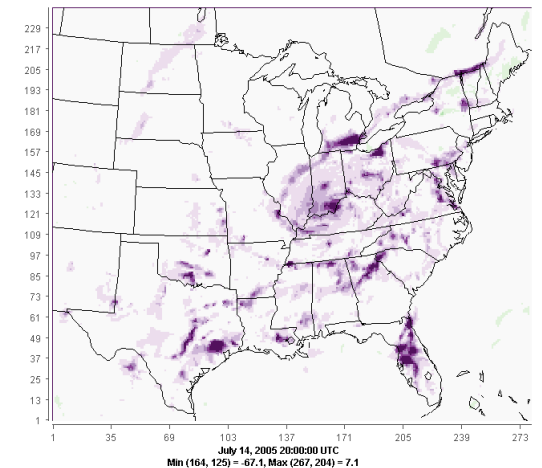
Layer 1 O3[1]-O3[2]

1-Hr Cloud Optical Depth

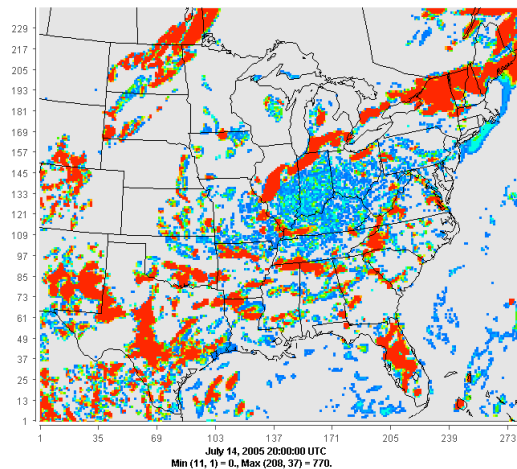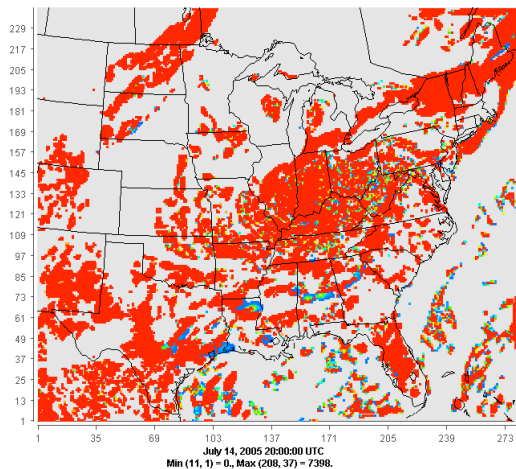## Difference Plots: Sens - Base
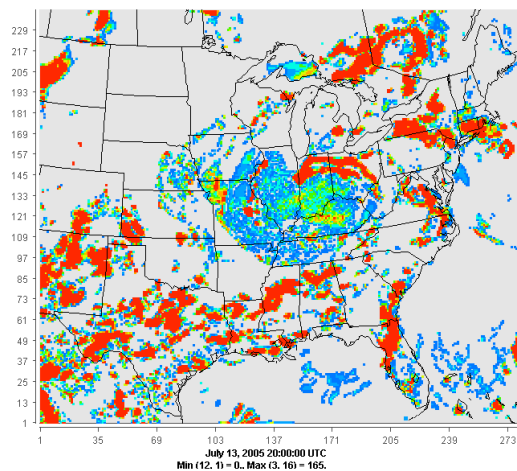
July 13 - Base
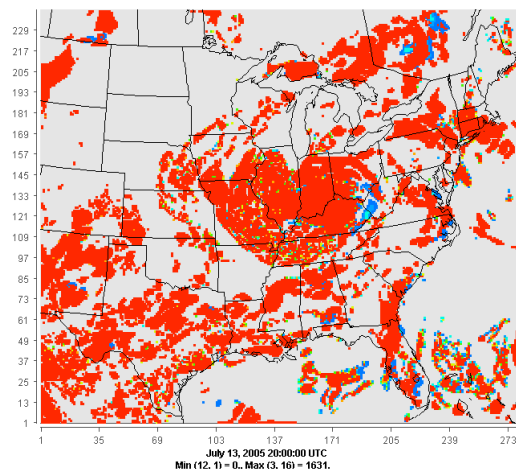
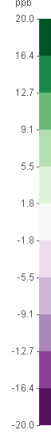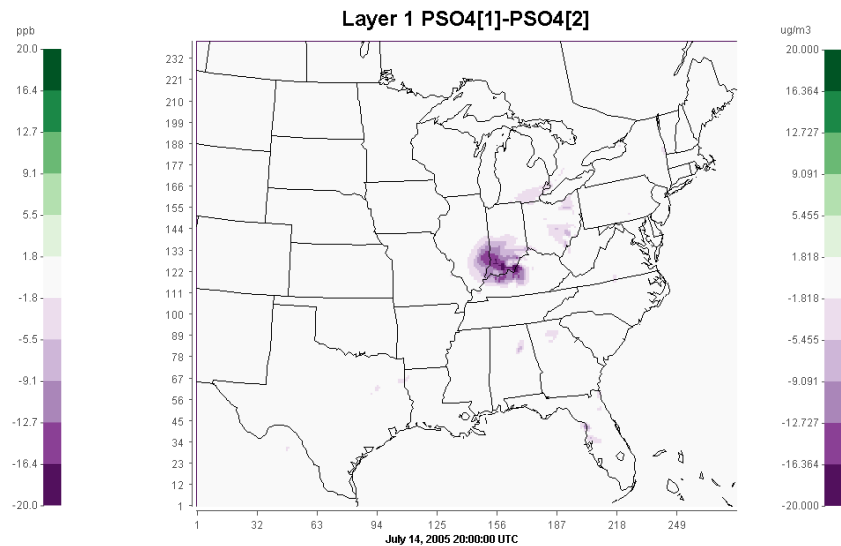### July 13 – COPD1 sens
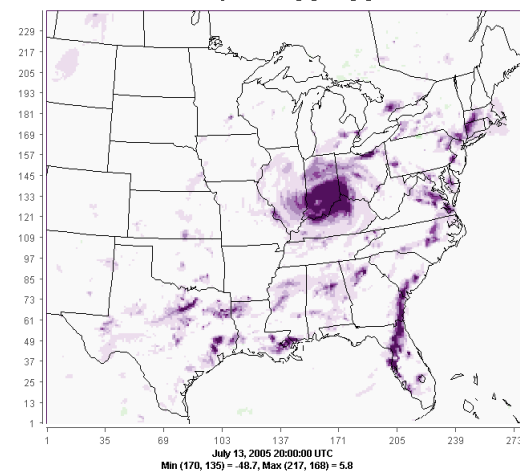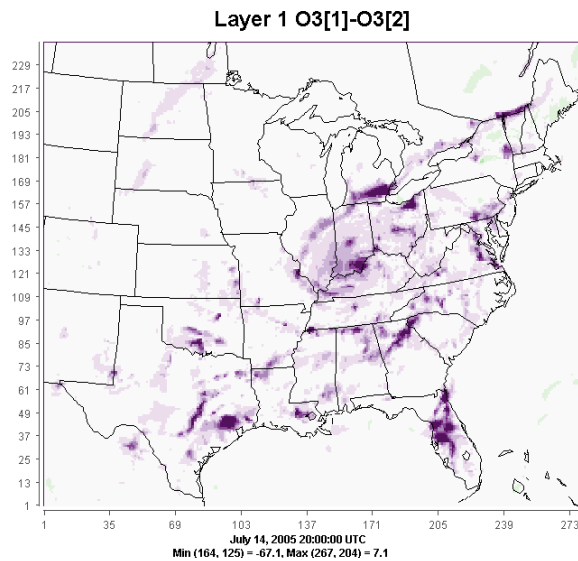

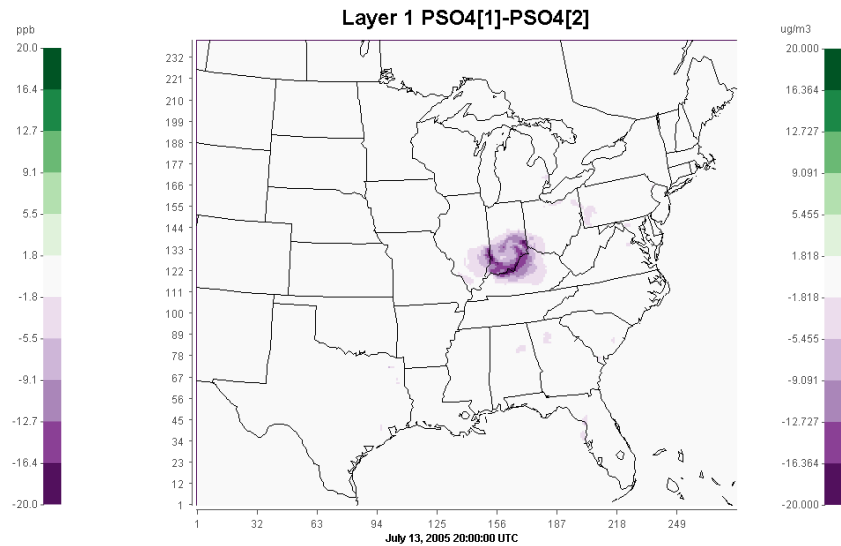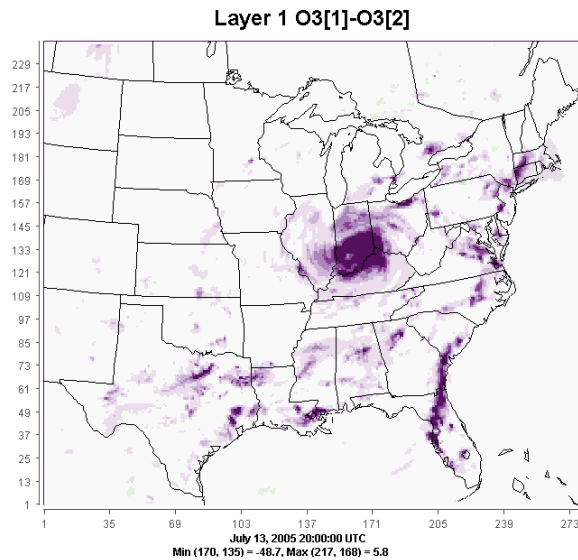**Layer 1 O3[1]-O3[2]**

July 14 - Base

July 14 – COPD1 sens
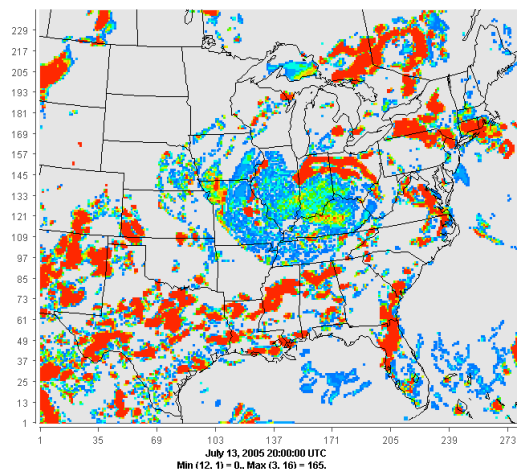

Layer 1 O3[1]-O3[2]
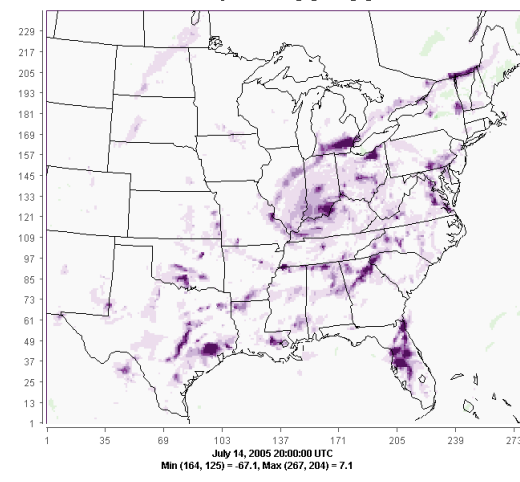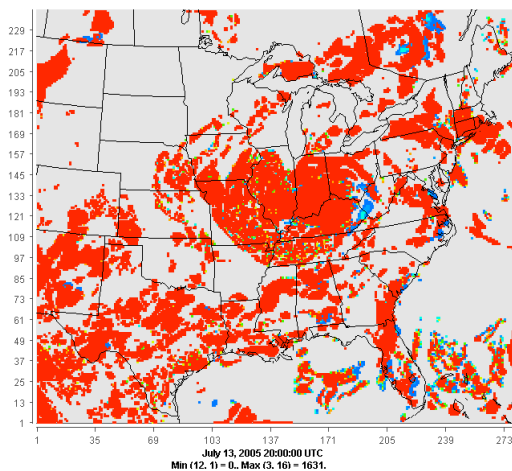
1-Hr Ozone and PM2.5 Sulfate Difference Plots
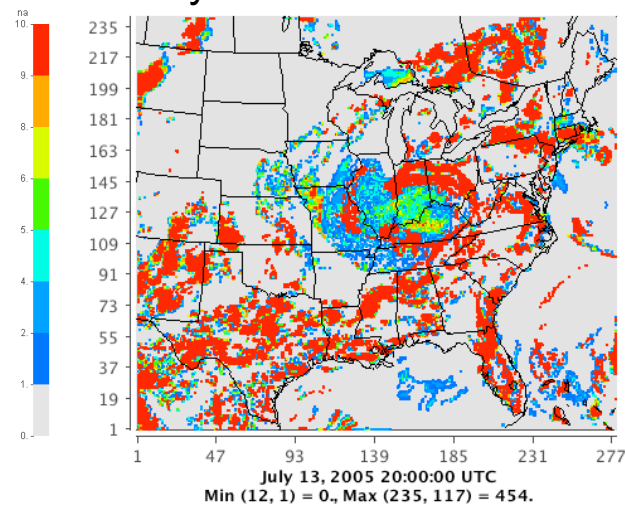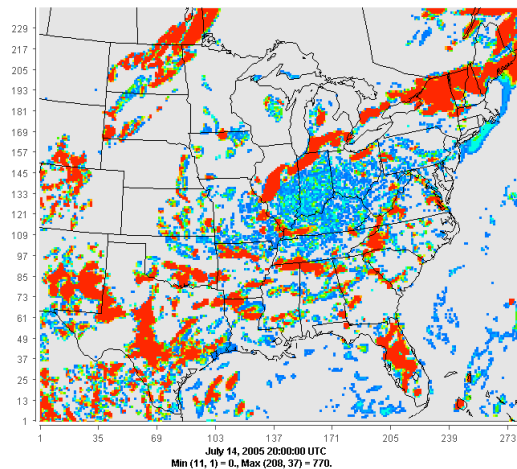
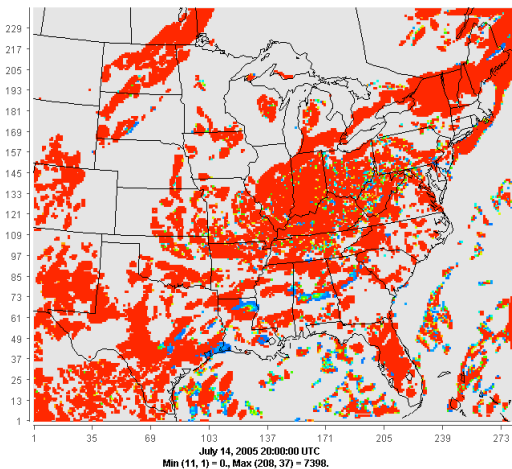# 1-Hr Cloud Optical Depth
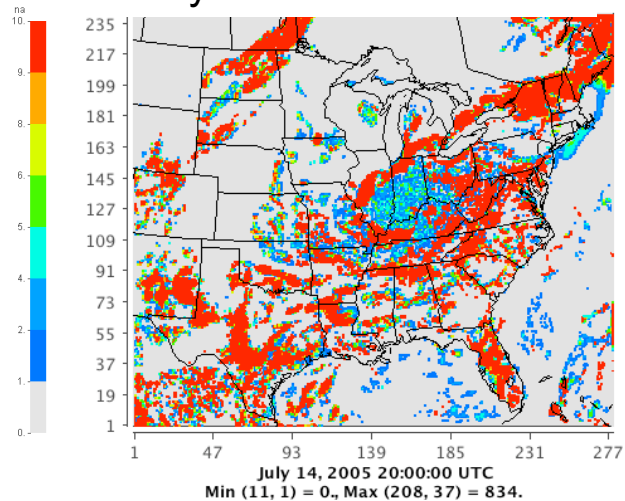

July 13 - Base

July 13 – COPD1 sens

July 13 – COPD2 sens
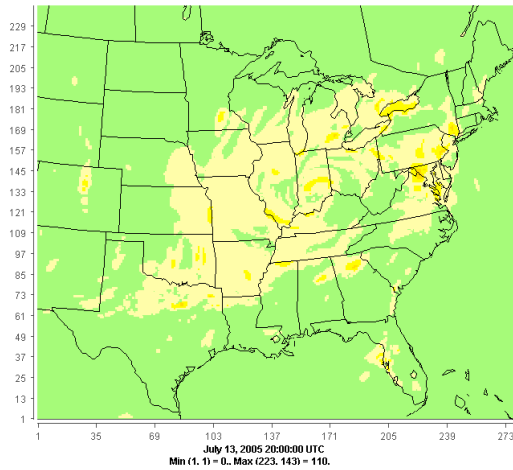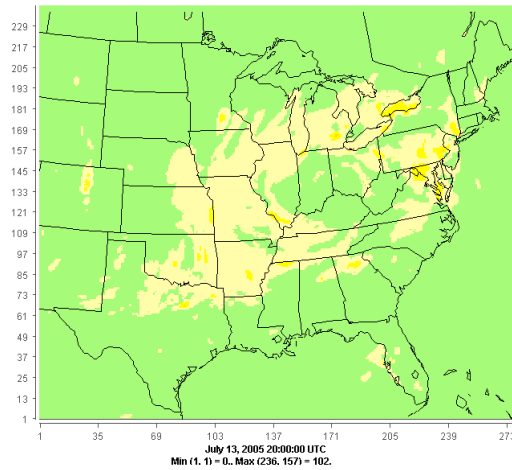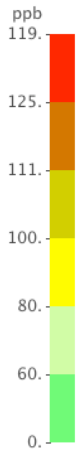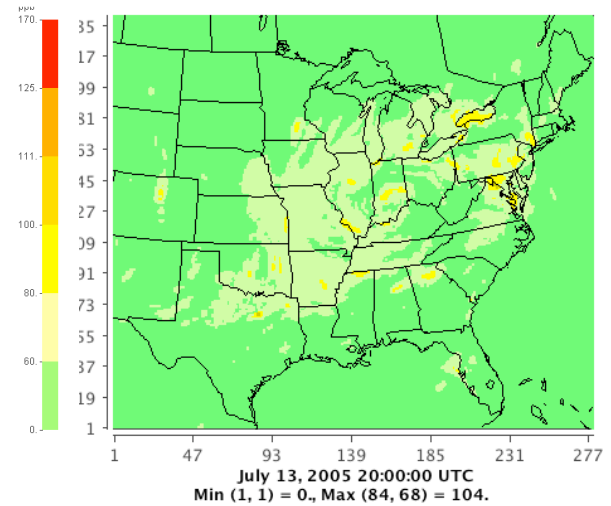
July 14 - Base

July 14 – COPD1 sens

July 14 – COPD2 sens

1-Hr Ozone
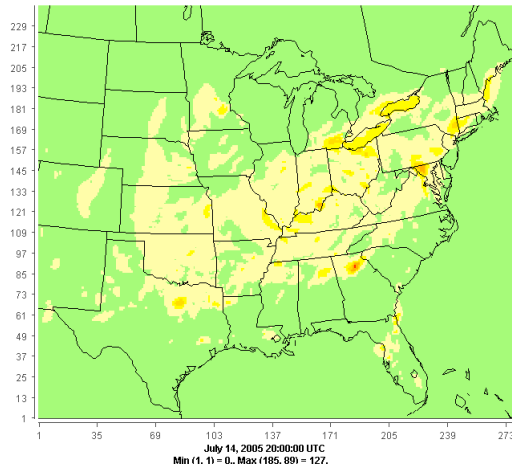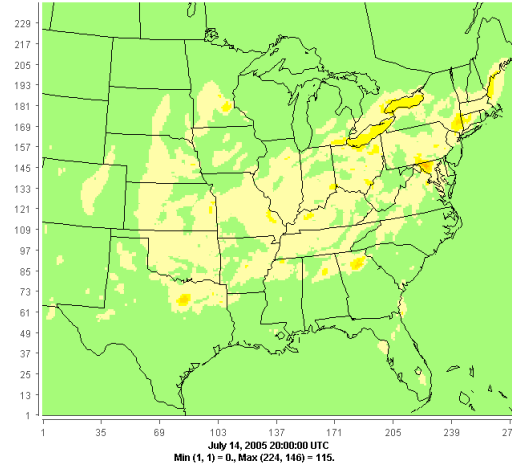

July 13 - Base

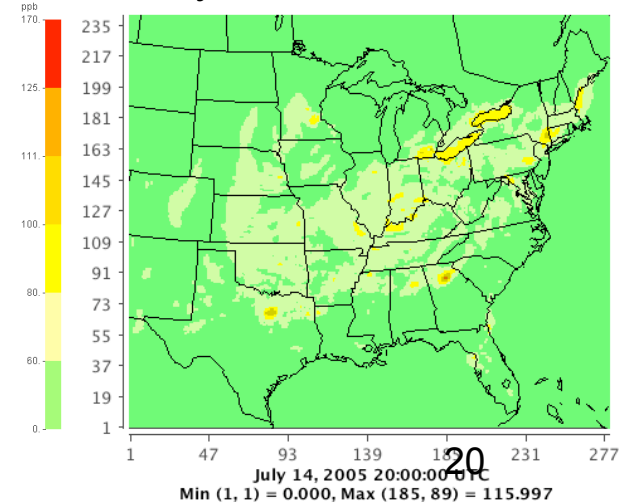July 13 – COPD1 sens

July 13 – COPD2 sens

July 14 - Base

July 14 – COPD1 sens

July 14 – COPD2 sens

Remarks

- Ozone over-predictions in the Ohio Valley are minimized when cloud optical depth is increased, particularly using the aggressive approach in COPD1

- Increasing the cloud optical depth decreases PM2.5 sulfate formation

- Model performance for sulfate needs to be examined to determine if this signal is directionally appropriate

- It is unclear whether the COPD routine needs to be changed or if the moisture fields output from MM5 are under-estimating moisture; CMAQ ozone estimates match observations well in this scenario

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